DRAFT

GPS Data Accuracy Standard

U.S. Bureau of Land Management
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The GPS Data Accuracy Standard consists of the following sections.

Section 1: Introduction

The GPS Data Standard is intended to provide direction for testing and reporting GPS accuracy in a consistent and statistically meaningful way. The Standard provides direction on matching GPS equipment and field procedures to the various GIS accuracy requirements of the agency. The Standard is based on a review of past agency and Federal accuracy standards with the intent of providing direction that is consistent with current Federal FGDC standards, specifically, the Federal Geographic Data Committee (FGDC), Geospatial Positioning Accuracy Standards, Part 3, NATIONAL STANDARD FOR SPATIAL DATA ACCURACY, FGDC-STD-007.3-1998. (NSSDA). (Appendix 2).

The GPS Data Accuracy Standard provides GPS Accuracy Testing Guidelines (Section 2) for consistent and repeatable testing and accuracy reporting. These test procedures will be used by the U.S. Forest Service and BLM to test and report the accuracy of GPS equipment and/or procedures at designated GPS test networks. The results will be published in a Table of Tested GPS Accuracies (Section 3) that lists the tested accuracies under various canopy conditions.

The GPS Data Standard does not define threshold accuracy values nor define the minimum accuracy required for a given GIS theme or application. The GIS data steward or application manager is responsible for deciding the accuracy values that are acceptable on a theme-by-theme basis.

This Standard provides two methods for GPS users to document that the accuracy of the data meets the required accuracy for intended GIS layer. Users can either statistically test and report the ***tested*** accuracy of their own GPS data sets following the GPS Accuracy Testing Guidelines in Section 2, or, they can report the ***expected*** accuracy of their GPS data set if the equipment they used has already been tested in similar canopy conditions and published in the Table of Tested GPS accuracies in Section 3.

GPS users can use the Table of Tested GPS Accuracies to select the GPS equipment and field procedures that meet the accuracy requirements set by the data steward. This Table also allows the reporting of “expected accuracy” of GPS data for projects that use similar equipment, similar field procedures, and have similar canopy conditions, thus eliminating the need for costly testing of each data set by each GPS user. When data is logged using untested GPS equipment, procedures or canopy conditions, users should test their own *data sets* using the Testing Guidelines.

The GPS Data Standard is applicable to GPS data logged with: 1) Resource / Mapping GPS receiver, defined as a C/A code receiver that allows user configurable critical settings (DOP, SNR, elevation mask, logging rate) and uses pseudorange data suitable for differential corrections (real-time or post-processed), 2) Recreation / Navigation GPS receiver**:** defined as C/A code or P/Y receiver that is generally not user configurable for critical settings. To support agency activities in forested conditions, the Standard will emphasize the reporting of the accuracy of these types of receivers under forest canopy.

GPS Data Standard Development Procedures

This draft data standard is directly adopted from the U.S. Forest Service draft “GPS Data Accuracy Standard” with the exception of changes tailored to specific BLM GIS data dictionaries.

The U.S. Forest Service GPS Steering Committee requested the development of the Forest Service Standard at their April 10, 2002 meeting, in San Diego, California. The Steering Committee was requested to develop these standards by line and staff officers at the national, regional and forest level due to frequent questions of the accuracy, quality and suitability of various sources of GPS data used in GIS applications for land management decisions.

Acknowledgement is given to Ken Chamberlain, formerly a Land Surveyor, U.S. Forest Service, Region 6, and now a Land Surveyor, Oregon State Office, U.S. Bureau of Land Management, for writing the draft Forest Service standard.

Relationship of GPS Data Standard to Existing Federal Data Standards

This GPS Data Standard is designed to comply with the Federal Geographic Data Committee (FGDC), Geospatial Positioning Accuracy Standards Part 3, NATIONAL STANDARD FOR SPATIAL DATA ACCURACY, FGDC-STD-007.3-1998. (NSSDA).(Appendix 2)

The FGDC specifies that the FGDC Geospatial Positioning Accuracy Standards be used to evaluate and report the positional accuracy of geospatial data produced, revised, or disseminated by or for the Federal Government. "Executive Order 12906 Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure" designates the FGDC as responsible for setting these standards. (Appendix 2)

The NSSDA was designed to replace the National Map Accuracy Standard (NMAS). The Bureau of the Budget developed NMAS in 1947. The applicability of NMAS is limited to graphic maps, as accuracy is defined by map scale. The NSSDA was developed to report accuracy of digital geospatial data that is not constrained by scale. The USGS used NMAS in the production of the topographic map series.

Characteristics of The National Standard for Spatial Data Accuracy are:

- Does not specify threshold accuracy. GIS managers set accuracy requirements for their applications.
- Tests and reports positional accuracy so users can directly compare accuracy of data for their applications.
- Compares data to test points with positions established at a higher accuracy standard.
- Reports accuracy based on Root Mean Square Error (RMSE) reported **at 95% confidence** at ground scale.
- Minimum number of test points is 20.
- Horizontal Accuracy =1.7308*RMSEr.
- Vertical Accuracy = 1.96*RMSEz.

Characteristics of The National Map Accuracy Standard are:

- Defines a threshold accuracy (pass / fail).
- Accuracy is scale dependent:
    - 12.2 Meters (40 Ft) for 1:24000 scale: Puerto Rico, Hawaii, and Continental US
    - 32.2 Meters (105.6 Ft) for 1:63,360 scale: Alaska
- Reports accuracy at **90% confidence level** at the map scale.
- Horizontal Accuracy is 1.5175 * RMSEr.
- Vertical Accuracy = 1.645 * RSMEz.

Relationship of GPS Data Standard to Existing Oregon BLM GIS Data Standards

Several Oregon BLM GIS themes are referenced to NMAS 1947 accuracy standards.

NMAS accuracy relative to NSSDA:

NMAS uses a 90% confidence level value and the GPS Data Standard uses the NSSDA 95% confidence level; therefore, the conversions are listed below. (Appendix 3 Formulas)

1. For data required to meet the NMAS accuracy requirement of 1:24,000 scale maps:
   (Puerto Rico, Hawaii, and Continental US)
   - NMAS at 90% confidence level= 12.2 Meters (40 Feet)
     Expressed as NSSDA:
   - NMAS at 95% confidence level = 13.9 Meters (45.6 Feet)

2. For data required to meet the accuracy of 1: 63,360 scale maps: Alaska
   - NMAS at 90% confidence level = 32.2 Meters (105.6 Feet)
     Expressed as NSSDA:
   - NMAS at 95% confidence level = 36.7 Meters (120.4 Feet)

There are currently several Oregon BLM GIS spatial data standards that have attribute fields for reporting GPS accuracy; however, none of these require the reporting of the confidence level of the accuracy stated.

The Grazing Allotments and Pastures, Noxious Weeds, Fire Water, and Wildlife Observation Sites Spatial Data Standards all have a common "Location Accuracy Code" attribute

> "Locational Accuracy Codes:
>
> GPS :
> GPS1 = within 3 feet.
> GPS2 = within 30 feet.
> GPS3 = within 300 feet."

The Interim Ground Transportation Field and Attribute Definitions have two attribute descriptions for GPS allowable under 43, Spatial Data Source:

> "Resource Grade GPS 3-7 meters (differential correction)
> Submeter Grade GPS (differential correction)"

The Geographic Coordinates Spatial Data Standard has a Point Reliability Code attribute with a list of values allowable including the following:

"0 = Default/unknown
1 = 1 foot or less
2 = 3 feet or less
3 = 10 feet or less
4 = 40 feet or less
5 = 100 feet or less
6 = 200 feet or less"

It is recommended that that Data Standard accuracy fields for reporting GPS accuracy be revised and updated to require reporting of that accuracy at the 95% confidence level to be in compliance with FGDC Geospatial Positioning Accuracy Standards.

Section 2: GPS Testing Procedures

Accuracy Test Guidelines

GPS Accuracy is tested comparing GPS measurements with independently established coordinates of higher accuracy. NSSDA specifies that a minimum of 20 check points shall be tested and that check points tested should be distributed to reflect the geographic area of interest and the distribution of error in the dataset.

To adapt the NSSDA for GPS testing, the number of known check points can be less than 20; however, the number of measurement sets on the check points should be much greater than 20. Test data will be more repeatable and statistically valid with larger sample sizes.

To avoid systematic errors due to satellite constellation bias, data should be logged at times that are well distributed throughout the day. To avoid systematic errors due to specific canopy conditions, data should be logged at all check points in the network. This is especially true for sites with heavy canopy.

The Forest Service maintains a set of GPS test networks at locations across the country. These sites provide the unique characteristic of having known independently established positions under forest canopy. GPS accuracy in open conditions is relatively well documented and understood. However the degree of GPS accuracy degradation under forest canopy is not well documented. Since much of the GPS use in the Forest Service will take place in forested locations, systematic study and reporting of this is required. The various test sites were selected to create a sample of the forest types and canopy conditions found on national forest lands. Additional test sites may be added to this system in the future.

The GPS test networks consist of a set of monumented check points, each of which has independently established coordinates. The coordinates of the check points at each site were determined by a combination of carrier phase GPS (survey grade) and conventional theodolite/EDM survey methods. The GPS measurements were tied to the National Spatial Reference System via the state High Accuracy Reference Network; only horizontal coordinates are published for these networks. Test Network coordinates are generally accurate to less than 5 cm (95% confidence level).

Tests of GPS accuracy in open conditions with no forest canopy should be made using monumented and published geodetic positions from the National Spatial Reference System. These can also serve as "control group" sites for testing in canopy.

The Forest Service GPS test network site locations and descriptions are listed in APPENDIX 4

Steps for Testing of GPS accuracy:

1. Test Site Selection
2. Receiver Configuration
3. Observation Length
4. Data Logging
5. Data Processing
6. Compute Accuracy
7. Documentation and Reporting

1. Test Site Selection
A test site should be selected based on the canopy type and density where the GIS data will be logged.

2. Receiver Configuration

When making receiver tests all receiver configuration variables should be noted in the test documentation.

Almanac Files: Receivers should be turned on and allowed to receive GPS signals for approximately 20 minutes before the tests are run. This procedure will insure that a current almanac is stored in the receiver before any test data is recorded.

Positioning Mode: A minimum of 4 satellites should be observed. Only Three-dimensional (X, Y, and Z) positions should be logged. Two-dimensional data is not acceptable for test data.

Elevation Mask: The minimum satellite elevation mask should be 15 degrees above the horizon, if user configurable.

Antenna Type: The receiver antenna type, i.e. internal or external, should be recorded. External antennas have been found to have an effect on both the accuracy and efficiency of the GPS data logged under canopy. It is recommended that receivers with manufacturer supplied external and internal antennas be tested with both to assess any differences in performance. The test should use an antenna height equivalent to those used for GIS fieldwork and the height should be documented.

PDOP or EPE: The Position Dilution of Precision (PDOP) and/or the manufacturers Estimated Position Error (EPE) values used in the test should be logged if the receiver is configurable to do so. This data will allow the analysis of the horizontal accuracy based on specific PDOP or EPE settings.

SNR: The Signal-to-Noise (SNR) used in the test should be documented if the SNR mask is configurable.

Data Logging Rates: Logging rates should be the same as those used to log GIS data. Commonly used settings are 1 position / second for point features and 1 position / 5 seconds for line (arc) and area (polygon) features.

DGPS Signals: When using real-time DGPS, select the base with the strongest signal regardless of whether that base is the closest to the test site. If the receiver configuration allows reception of multiple real time sources, it should be set for one frequency only. Systematic errors in the position can be introduced if the receiver is configured to use multiple broadcast signals due to unexpected changes in the correction source.

3. Observation Length

Point Features: Receiver accuracy for *point* features can be determined using several approaches:

One method is a single position test. In this test, a single GPS postion is loggedc per point feature, then compared with the independent data. Some Recreation / Navigation receivers can only operate in a single point mode; they cannot be configured to log multiple positions into one “waypoint”; i.e., they do not support position averaging.

Another method is a systematic analysis of the relationship between the number of positions and accuracy. This method is used to determine the optimum number of GPS *positions* that should be logged to create one *point* feature. The accuracy of a point position is analyzed relative to the number of positions recorded. Using this method allows the tester to determine the minimum number of positions for each point feature that will be used in the data-logging portion of the test.

Yet another method is to adopt a commonly used number of positions for each point feature. The feature coordinates are the average of all the positions recorded. With this method, each point feature could consist of the manufacturers recommended number of positions or for example under canopy conditions be increased to a larger number of positions such as 30, 60, 120, or more. Often more positions are required under canopy than are required at open sites.

Line/Polygon Features: Line (arc) and area (polygon) features consist of a series of linked single point positions; therefore, single point tests can be used to estimate the accuracy of line and area features.

4. Data Logging

To avoid systematic errors due to specific canopy conditions, data should be logged at all check points in the network. To avoid systematic errors due to satellite constellation bias, data should be logged at times that are well distributed throughout the day.

5. Data Processing

Data processing is considered to be all operations and computer processing made to the raw GPS data logged in the field. . The data differential correction method used, e.g., real-time or post processed should also be noted. To allow duplication of test results, the data processing methods and procedures used for data downloading, differential correction, and export should be documented. This should include all the software packages and version used. If data is differentially corrected, the base and the distance from the test course should be noted.

6. Compute Accuracy

The NSSDA uses root-mean-square error (RMSE) to estimate positional accuracy. RMSE is the square root of the average of the set of squared differences between dataset coordinate values and coordinate values from an independent source of higher accuracy for identical points. Accuracy is reported in ground distances at the 95% confidence level.

The accuracy should be computed using the NSSDA error analysis spreadsheet in Appendix 2.

Although not a measure of GPS accuracy, it is recommended that receiver reports make at least a cursory examination of receiver efficiency. Receiver Efficiency = number of positions logged / (total time data was logged in seconds/ data logging rate). Some GPS receiver critical settings can yield relatively accurate positions; however, due to low efficiency, logging GIS data with those settings could take a very long time.

7. Documentation and Reporting

Documenting detailed information about the methods, procedures, and equipment used in GPS testing will make the test results useful and valid for application by others. Minimum documentation should include the receiver type, antenna type, observation length, receiver settings (SNR, PDOP, logging rates, elevation mask, etc), number of positions per point feature, differential -correction method and base station used (if applicable), and any field other relevant field procedures. Specific information regarding the receiver serial numbers, model numbers, and software application versions should also be documented.

The accuracy of tests should be reported as NSSDA accuracy.

Section 3:

Note: In final version, this will probably be a link to a table that is frequently updated with new equipment tests.

Table of Tested GPS Accuracy

RECEIVER TYPE	COMMENTS	Open Open 95% (meters)	Medium Canopy 95% Lubrecht (meters)	Heavy Canopy 95% Powell (meters)	Heavy Canopy 95% Clackmas (meters)	Heavy Canopy 95% Hardwoods (meters)
Recreational Grade Receivers						
Magelan XL12 -single reading 1)	1 Position Reading	11			33	
Magelan Blazer 12 - single reading 1)	1 Position Reading	10			50	
Magellan GPS Companion - Single Reading	1 Position Reading		20-24			
Garmin eTrex - Single Reading 1)	1 Position Reading	10			63	
Garmin GPS III - Single Reading	1 Position Reading	2.6				
Garmin GPS III - Single Reading 1)	1 Position Reading	4			68	
Garmin GPS III - Single Reading RT-corrected	1 Position Reading	2.6				
Garmin GPS III - Averaging 1)	60 Position Ave	3.5			30	
Garmin GPS III - with Real-time Beacon	60 Position Ave			2-16	15-17	
Garmin GPS Map76 - Single Reading	1 Position Reading					
Garmin GPS Map76 - Single Reading RT-corrected	1 Position Reading					
Garmin GPS Map76 - Single Reading With WAAS	1 Position					

	Reading					
Garmin GPS Map76 - Averaging	60 Position Ave		26	3-20	17-20	
Garmin GPS Map76 with Real-time Beacon				3-20	22	
Garmin GPS Map76 with WAAS				3-20	22	
Trimble Pathfinder Pocket - Single Reading	1 Position Reading					
Trimble Pathfinder Pocket - Averaging	60 Position Ave	5	9-13			
Trimble Pathfinder Pocket with Real time Beacon						
Resource Grade Receivers						
Trimble Pro XR- un-corrected	1 Position Ave					
Trimble Pro XR- Post-processed	1 Position Ave					
Trimble Pro XR- un-corrected	1 Position Ave					
Trimble Pro XR	5 Position Ave					
Trimble Pro XR - RT (PDOP 8, SNR 4) 1)	5 Position Ave	1	2-3	0.3-3.2	10	
Trimble Pro XR - Post Processing (PDOP 8, SNR 4) 1)	5 Position Ave	.5	2.9		8	
Trimble Pro XR	60 Position Ave		5.7	2.2-7.0		
Trimble Pro XR - RT (PDOP 8, SNR 4) 1)	60 Position Ave	1	2-4	6	6	
Trimble Pro XR - Post Processing (PDOP 8, SNR 4) 1)	60 Position Ave	.5		0.6-2.7	6	
Trimble GeoExplorer 3 Uncorrected	1 Position Ave					
Trimble GeoExplorer 3 Post-Processed	1 Position Ave					
Trimble GeoExplorer 3 RT -Corrected	1 Position Ave					
Trimble GeoExplorer 3	1 Position Ave					
Trimble GeoExplorer 3	5 Position Ave					
Trimble GeoExplorer 3 - RT	5 Position Ave		7-10	12	24	
Trimble GeoExplorer 3 - Post Processed	5 Position Ave					
Trimble GeoExplorer 3	60 Position Ave			1-14	17	
Trimble GeoExplorer 3 - RT	60 Position Ave		8-13	2-10	14-19	
Trimble GeoExplorer 3 - internal, PDOP 6, SNR4, P-P 1)	5 Position Ave	6			36	
Trimble GeoExplorer 3 - External Ant., PDOP 6, SNR4, P-P 1	5 Position Ave	2			33	
Trimble GeoExplorer 3 - internal, PDOP 6, SNR4, P-P 1	60 Position Ave	6			18	
Trimble GeoExplorer 3 - External Ant, PDOP 6, SNR4, P-P 1	60 Position Ave	2			13	
1) Mancebo & Chamberlain 2000						

Section 4: Accuracy Reporting and Metadata

Accuracy Reporting:

NSSDA provides a consistent means of reporting accuracy of GIS data. The accuracy of GPS data used in the GIS data set is reported at the 95% confidence level, in ground distances, in the units of the GIS.

The accuracy of agency GPS data may be reported by one of two methods: 1) a report based on the expected accuracy of the GPS data based on previously compiled accuracy tests of similar equipment used in similar conditions, per the

Table of Tested GPS Accuracies (Section 3), or 2) a report of the accuracy of the GPS data set based on NSSDA testing of the actual GIS data set.

Generally only horizontal GPS data is exported to the BLM GIS; so only horizontal accuracy of GPS data is recorded in these examples.

1) Reporting expected accuracy of GPS-derived GIS data based upon Forest Service or other NSSDA published receiver test.

When the GPS accuracy values listed in the Table of Tested GPS Accuracies are used, report accuracy using the following “compiled to meet” statement:

Report accuracy at the 95% confidence level for data *produced according to procedures that have been demonstrated to produce data with particular horizontal accuracy values* as:
Compiled to meet ____ (meters, feet) horizontal accuracy at 95% confidence level

2) Reporting tested accuracy of GPS-derived GIS data based upon your own NSSDA test results.

When the GPS accuracy is directly tested by the user, report accuracy using the following "tested" statement:

Report accuracy at the 95% confidence level for data *tested* for horizontal accuracy as:
Tested ____ (meters, feet) horizontal accuracy at 95% confidence level

Metadata Reporting:

The NSSDA method of stating accuracy is consistent with the FGDC metadata requirements. The reported horizontal accuracy values can travel with the GIS dataset as metadata. Accuracy reporting is an important element of the Federal Geographic Data Committee, Content Standard for Digital Geospatial Metadata, FGDC STD-001-1998. Listed below are specific examples of accuracy reporting from that document:

For GPS data, report the accuracy value in digital geospatial metadata (Federal Geographic Data Committee, 1998, Section 2), as appropriate to dataset spatial characteristics:
(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Assessment/Horizontal_Positional_Accuracy_Value)

Enter the text “National Standard for Spatial Data Accuracy” for these metadata elements (Federal Geographic Data Committee, 1998, Section 2), as appropriate to dataset spatial characteristics:
(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Assessment/Horizontal_Positional_Accuracy_Explanation)

Provide a complete description on how the accuracy values were determined in metadata, as appropriate to dataset spatial characteristics, (Federal Geographic Data Committee, 1998, Section 2):
(Data_Quality_Information/Positional_Accuracy/Horizontal_Positional_Accuracy/Horizontal_Positional_Accuracy_Report)

Accuracy of existing or legacy spatial data and maps may be reported, as specified, according to the NSSDA or the accuracy standard by which they were evaluated.

In addition to the accuracy statement, the following information should be provided to the theme metadata compiler:

- Coordinate system & Datum used: Generally UTM in NAD27
- Projection: Generally UTM
- Units.
- Attribute Description (GPS data dictionary; features, attributes and attribute values)
- Source – Receiver type, antenna type, receiver settings (SNR, PDOP, logging rates RATES, Elevation Mask, etc), Number of positions per point feature, Correction method (if applicable), and any field other relevant field procedures,

References:

1. Federal Geographic Data Committee, Geospatial Positioning Accuracy Standards, Part 3: National Stand for Spatial Data Accuracy, FGDC-STD-007.2-1998.

2. Federal Geographic Data Committee, Geospatial Positioning Accuracy Standards Part 4, Engineering, Construction, and Facilities Management, FGDC-STD-007.4-2002.

3. Federal Geographic Data Committee, Content Standard for Digital Geospatial Metadata, FGDC STD-001-1998.

4. Federal Geographic Data Committee, A Proposal for a National Spatial Data Infrastructure Standards Project.

5. Executive Order 12906, Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure.

6. Forest Service, Geometronics Service Center, Guidelines for Digital Base Map Updates, EM 7140-24.

7. National Map Accuracy Standard, U.S. Bureau of the Budget, 1947.

8. Positional Accuracy Handbook, Using the National Standard for Spatial Data Accuracy to measure and report geographic data quality, October 1999, Land Management Information Center, Minnesota Planning.

9. Oregon/Washington BLM State Data Dictionary, http://www.or.blm.gov/gis/data/management/index.asp.

10. Ministry of Forests Procedures and Guidelines for Operational Forest Resource Survey and Mapping Using Global Positioning System Technology, February 2001, Version 3, Province of British Columbia.

11. Global Positioning System Standard Positioning Service Performance Standard, October 2001, Department of Defense.

Appendix 1: Application of the GPS Data Standard for GIS

The following examples illustrate some applications of the GPS Data Standard in a GIS project:

A GPS Mapping Project:
You are assigned to map heritage resource site point features for inclusion as corporate data in the forest GIS. The GIS data steward has decided that the theme will be mapped to meet NMAS per direction in the GIS Data Dictionary. The project is in heavy canopy conditions in western Washington. You have a Garmin eTrex, a Trimble GeoExplorer3 , and a Pathfinder Professional GPS receiver available on the district. Which receiver should you use to log the data?

Use the following steps to apply the GPS Data Standard for GIS. Convert NMAS to GPS Data Standard using the formulas in Appendix 2, or use the accuracy values in Section 1. Select a receiver from the Table of Tested GPS Accuracy in Section 3 that meets the 13.9 meter accuracy in heavy canopy. One choice would be a Pathfinder ProXR. Log data using the same configuration listed in the table: number of positions per feature, receiver settings (PDOP and SNR), data processing method, etc. Export the data to GIS. Report accuracy at the 95% confidence level for data produced according to procedures that have been demonstrated to produce data with particular horizontal accuracy values as: *Compiled to meet* 13.9 (meters) horizontal accuracy at 95% confidence level Report the metadata: Horizontal_Positional_Accuracy_Value = 13.9 meters, Hororizontal_Positional_Accuracy_Explanation = National Standard for Spatial Data Accuracy, Horizontal_Positional_Accuracy_Report = List the receiver type, settings, software used, etc. per Section 4.

Testing a GPS receiver Accuracy:
You have mapped burned areas for a fire recovery team with a new model Garmin GPS receiver. There is no test data available in the Table of Tested GPS Accuracy for this model. The fire area is in open pine forests in western Montana. The GIS data steward needs to report the accuracy of the GIS layer. How should the accuracy be reported?

The Standard allows two methods: 1) Deduce that the receiver performance will be similar to other recreation / navigation type GPS receivers used in open canopy. 2) Test the receiver using the GPS Data Standard.

To test the new receiver, use a set of known check points positioned to a higher accuracy standard. In this case, the Lubrecht Test network is nearby and has similar canopy conditions. Use the Test Guidelines in Section 2 to log data at the test course using the same data logging and receiver settings that were used for the fire mapping. Log data four times at each of the seven control points. You will now have a data set of 28 check points. Export this data to a spreadsheet, enter the known coordinates of the checkpoints, and then use the formulas

shown in Appendix 2 to make a NSSDA accuracy calculation. Per Section 2, document the test procedures.
For example, assuming your result is 11 meters, report accuracy at the 95% confidence level for data produced according to procedures that have been demonstrated to produce data with particular horizontal accuracy values as:
Tested to meet 11 (meter) horizontal accuracy at 95% confidence level.
Report the metadata: Horizontal_Positional_Accuracy_Value = 11 meters, Hororizontal_Positional_Accuracy_Explanation = National Standard for Spatial Data Accuracy, Horizontal_Positional_Accuracy_Report = List the receiver type, settings, software used, etc. per Section 4 under reporting.

Appendix 2: National Standard for Spatial Data Accuracy Spreadsheet

Figure 4. Horizontal accuracy statistic worksheet.

A Point number	B Point description	C x (independent)	D x (test)	E diff in x	F (diff in x) ^{2}	G y (independent)	H y (test)	I diff in y	J (diff in y) ^{2}	K (diff in x) ^{2} + (diff in y) ^{2}
								sum	
								average	
								$RMSE_r$	
								NSSDA	

Column	Title	Content
A	Point number	Designator of test point
B	Point description	Description of test point
C	x (independent)	x coordinate of point from independent data set
D	x (test)	x coordinate of point from test data set
E	diff in x	x (independent) - x (test)
F	(diff in x) ^{2}	Squared difference in x = (x (independent) - x (test)) ^{2}
G	y (independent)	y coordinate of point from independent data set
H	y (test)	y coordinate of point from test data set
I	diff in y	y (independent) - y (test)
J	(diff in y) ^{2}	Squared difference in y = (y (independent) - y (test)) ^{2}
K	(diff in x) ^{2} + (diff in y) ^{2}	Squared difference in x plus squared difference in y = (error radius) ^{2}
	sum	Σ [(diff in x) ^{2} + (diff in y) ^{2}]
	average	sum / number of points
	$RMSE_r$	Root Mean Square Error (radial) = average $^{1/2}$
	NSSDA	National Standard for Spatial Data Accuracy statistic = 1.7308 * $RMSE_r$

Appendix 3: Formulas

Horizontal Accuracy using NSSDA formulas:

Determine the radial Root Mean Square Error (RMSE) for the GPS data set:

$RMSE_r$ = sqrt[Σ ((Xdata - Xcheck)^2+(Ydata – Xcheck)^2)/n]

where:

Xdata , Ydata are the coordinates of the check point in the GPS data, i data, i
Xcheck , Ycheck are the coordinates of the check point in GPS test network.

Modify RMSE error to 95% probability:

$Accuracy_r = 1.7308 * RSME_r$

An alternate formula for RSMEr is:

= sqrt[(Σ(Ex^2 + Ey^2))/n)^2+(Std Deviation of Error)^2]

National Map Accuracy Standard (NMAS 1947) Conversion to National Standard for Spatial Data (NSSDA)

If error is normally distributed in each the x- and y-component and error for the x-component is
equal to and independent of error for the y-component, the factor 2.146 is applied to compute
circular error at the 90% confidence level (Greenwalt and Schultz, 1968). The circular map
accuracy standard (CMAS) based on NMAS is:

CMAS = 2.1460 * RMSEx = 2.1460 * RMSEy
= 2.1460 * $RMSE_r$ /1.4142
= 1.5175 * $RMSE_r$

Where,

RMSEx is the Root Mean Square Error in the X coordinate
RMSEy is the Root Mean Square Error in the Y coordinate

The CMAS (90% confidence) can be converted to accuracy reported at NSSDA $Accuracy_r$, (95% confidence)

$Accuracy_r = 1.1406 * CMAS_r$

Therefore, NMAS horizontal accuracy reported according to the NSSDA is:

1.1406* [S * (1/30")/12"] feet, or 0.0032 * S, for map scales larger than 1:20,000
1.1406* [S * (1/50")/12"] feet, or 0.0019 * S, for map scales of 1:20,000 or smaller

where S is the map scale denominator.

National Standard for Spatial Data Accuracy (95% confidence) from Circular Error Probable (50% confidence).

NSSDA accuracy = (1.7308*(RMSEr=5 meter CEP/0.83)).
NSSDA accuracy = 10.4 meters

Appendix 4: USFS GPS Test Networks

Powell, Idaho GPS Test Course
This GPS test site is on the Powell Ranger District of the Clearwater NF near Highway US 12 at the Idaho Highway Maintenance area about 12 miles west of Lolo Pass and about 55 miles SW of Missoula, MT. The test site is located near the Lochsa River. Mountains on the north and south sides of the course obstruct the view at an angle of 10 degrees. The canopy consists of large (24" to 42" d.b.h.) old growth cedar and spruce trees in a flat valley bottom with only a small amount of understory. At most stations, the canopy would be considered heavy. The course has 11 turning points or stations that outline a 12.019 acre polygon. The polygon can be divided to produce 2 smaller polygons.

For further information contact: Dick Karsky, Missoula Technology Development Center, 406-329-3921. email: dkarsky@fs.fed.us

Lubrecht, Montana Test Course
The Lubrecht Test Course is located at the Lubrecht Experimental Forest about 40 miles northeast of Missoula, MT. This course is a polygon with seven turning points (stations) and is located on gentle terrain, under a mixed lodgepole and ponderosa pine canopy. The trees are about 19 meters tall with a minimal understory. The canopy would probably be classified as a light to medium. Station B-31 is located in the open, with a clear view of the sky down to an angle of 15 degrees.

For further information contact: Dick Karsky, Missoula Technology Development Center, 406-329-3921 email: dkarsky@fs.fed.us

Clackamas, Oregon Test Course
The Clackamas Test Course is located on the Clackamas River Ranger District of the Mount Hood National Forest about 70 miles southeast of Portland Oregon. The course is located in Cascade Mountains of western Oregon. The course is on gentle terrain with no terrain obstructions above 15 degrees. The canopy at the course consists of heavy second growth Douglas-fir and western hemlock (trees about 24 to 40 inches d.b.h.) with a vine maple and red alder understory. At most stations, the canopy would be considered heavy. The course has 13 stations that outline a of 7.20 acre polygon.

For further information contact: Ken Chamberlain, 503-808-6387, email: ken_chamberlain@or.blm.gov.

Bedford, Indiana Test Course
The Bedford Test Course is located on the Hoosier National Forest, 11 miles from Bedford, Indiana. The site has gentle terrain under a dense canopy of uneven-aged oak, beech, and hickory trees typical of eastern hardwood forests, with canopy tops 31 to 37 meters (100 to 120 feet) above the ground. The test

course has seven turning points located on two finger ridges with one point in the bottom of the draw between the ridges. The polygon defined by the seven turning points contains 3.32 acres.

For further information contact: Dale Weigel, 812-277-3597, email: dweigel@fs.fed.us

Newtown Square, PA

This GPS Test Site is located in Ridley Creek State Park about 16 miles west of Philadelphia. This course consists of two polygons with 10 turning points (stations) under a heavy deciduous canopy dominated by large diameter poplar, oak, and beech. There are two additional control points (accurate to within 1.5 cm) located between the polygons in an open field. Ridley Creek State Park is characterized by gently rolling forested hills and meadows.

For further information contact: Richard A. McCullough, 610-557-4081, email: rmccullough01@fs.fed.us

Appendix 5: Existing Standards

Federal Standards:

United States National Map Accuracy Standards
With a view to the utmost economy and expedition in producing maps which fulfill not only the broad needs for standard or principal maps, but also the reasonable particular needs of individual agencies, standards of accuracy for published maps are defined as follows:

1. Horizontal accuracy. For maps on publication scales larger than 1:20,000, not more than 10 percent of the points tested shall be in error by more than 1/30 inch, measured on the publication scale; for maps on publication scales of 1:20,000 or smaller, 1/50 inch. These limits of accuracy shall apply in all cases to positions of well-defined points only. Well-defined points are those that are easily visible or recoverable on the ground, such as the following: monuments or markers, such as bench marks, property boundary monuments; intersections of roads, railroads, etc.; corners of large buildings or structures (or center points of small buildings); etc. In general what is well defined will be determined by what is plottable on the scale of the map within 1/100 inch.

Thus while the intersection of two road or property lines meeting at right angles would come within a sensible interpretation, identification of the intersection of such lines meeting at an acute angle would obviously not be practicable within 1/100 inch. Similarly, features not identifiable upon the ground within close limits are not to be considered as test points within the limits quoted, even though their positions may be scaled closely upon the map. In this class are timber lines, soil boundaries, etc.

2. Vertical accuracy, as applied to contour maps on all publication scales, shall be such that not more than 10 percent of the elevations tested shall be in error more than one-half the contour interval. In checking elevations taken from the map, the apparent vertical error may be decreased by assuming a horizontal displacement within the permissible horizontal error for a map of that scale.

3. The accuracy of any map may be tested by comparing the positions of points whose locations or elevations are shown upon it with corresponding positions as determined by surveys of a higher accuracy. Tests shall be made by the producing agency, which shall also determine which of its maps are to be tested, and the extent of the testing.

4. Published maps meeting these accuracy requirements shall note this fact on their legends, as follows: “This map complies with National Map accuracy Standards.”

5. Published maps whose errors exceed those aforestated shall omit from their legends all mention of standard accuracy.

6. When a published map is a considerable enlargement of a map drawing (manuscript) or of a published map, that fact shall be stated in the legend. For example, “This map is an enlargement of a 1:20,000-scale map drawing,” or “This map is an enlargement of a 1:24,000-scale published map.”

7. To facilitate ready interchange and use of basic information for map construction among all Federal mapmaking agencies, manuscript maps and published maps, wherever economically feasible and consistent with the uses to which the map is to be put, shall conform to latitude and longitude boundaries, being 15 minutes of latitude and longitude, or 7.5 minutes, or 3-3/4 minutes in size.
Issued June 10, 1941 U.S. BUREAU OF THE BUDGET
Revised April 26, 1943
Revised June 17, 1947

Executive Order 12906, Coordinating Geographic Data Acquisition and Access: the National Spatial Data Infrastructure
(Clinton, 1994, Sec. 4. Data Standards Activities, item d), "Federal agencies collecting or producing geospatial data, either directly or indirectly (e.g. through grants, partnerships, or contracts with other entities), shall ensure, prior to obligating funds for such activities, that data will be collected in a manner that meets all relevant standards adopted through the FGDC process."

Federal Geographic Data Committee (FGDC) Geospatial Positioning Accuracy Standards

FGDC Geospatial Positioning Accuracy Standards Part 3, NATIONAL STANDARD FOR SPATIAL DATA ACCURACY, FGDC-STD-007.3-1998, (NSSDA) implements a testing and statistical methodology for positional accuracy of fully georeferenced maps and digital geospatial data, in either raster, point, or vector format, derived from sources such as aerial photographs, satellite imagery, and ground surveys. The NSRS is the framework that references positions to the national datums. Positional accuracy of geodetically surveyed points in the National Spatial Reference System is reported according to Part 2, Standards for Geodetic Control Networks, Geospatial Positioning Accuracy Standards. NSRS points may also be selected as an independent source of higher accuracy to test positional accuracy of maps and geospatial data according to the NSSDA. The lead agency is the Department of the Interior, U.S. Geological Survey, National Mapping Division. The responsible FGDC unit is the Subcommittee on Base Cartographic Data.